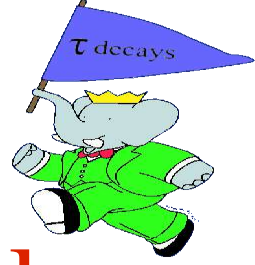

Search for Lepton Flavour Violation (LFV) in Three-Body Tau Decays At BaBar

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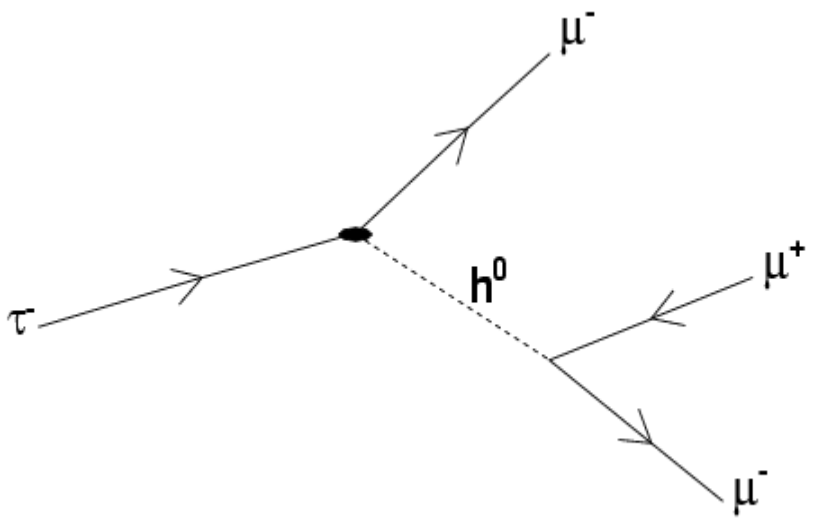
Outline

- Motivation for analyses ($\tau \rightarrow lll$ and $\tau \rightarrow lhh$)
- The BaBar detector
- Outline of analysis technique
- Results
- Conclusions

Motivation for LFV Analyses

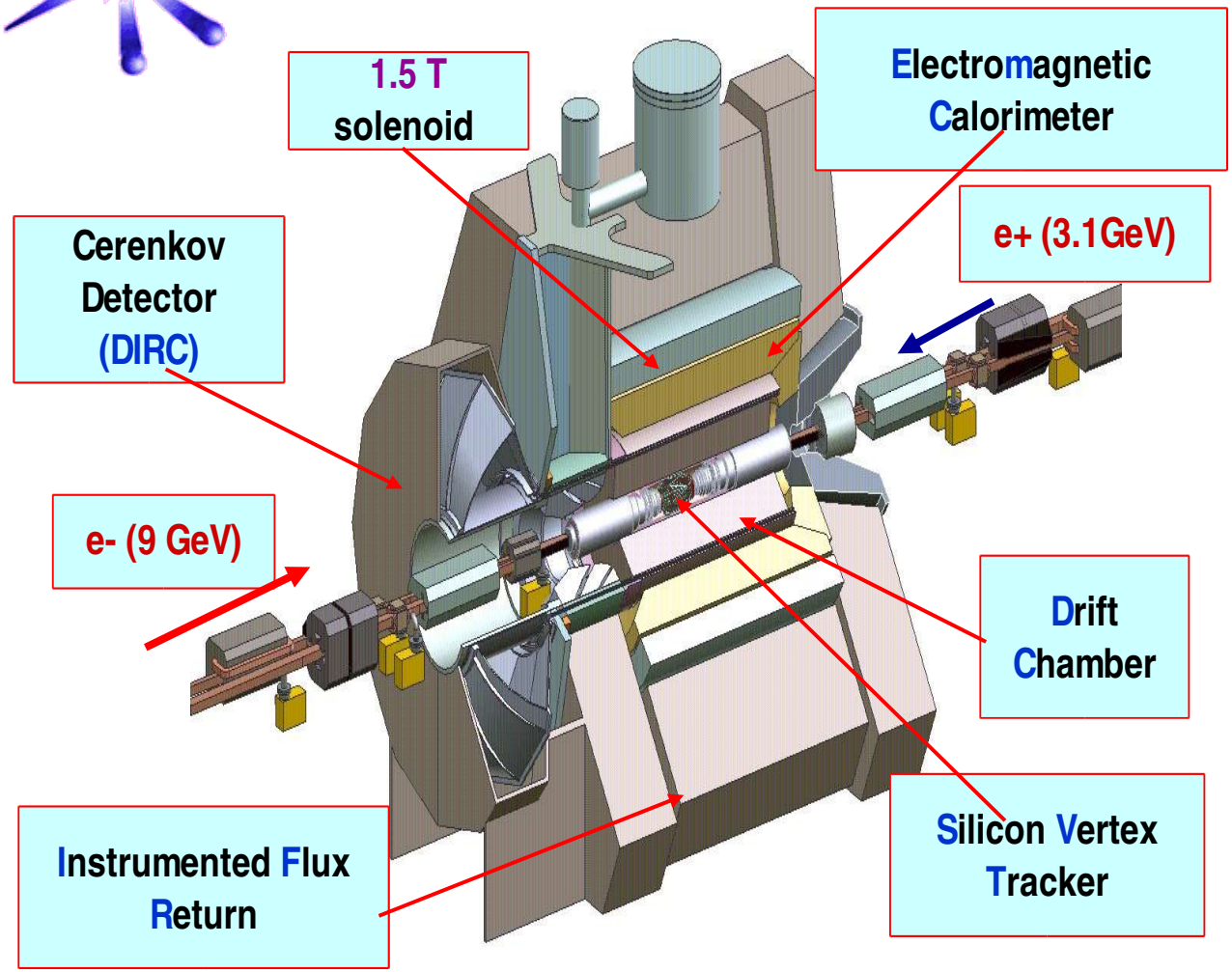
- With known υ mixing expect small (~10^{-14}) LFV
- LFV sensitive to Beyond Standard Model physics
- Models allow B($\tau \to lll$) and B($\tau \to lhh$) in range 10^{-20} to 10^{-6}

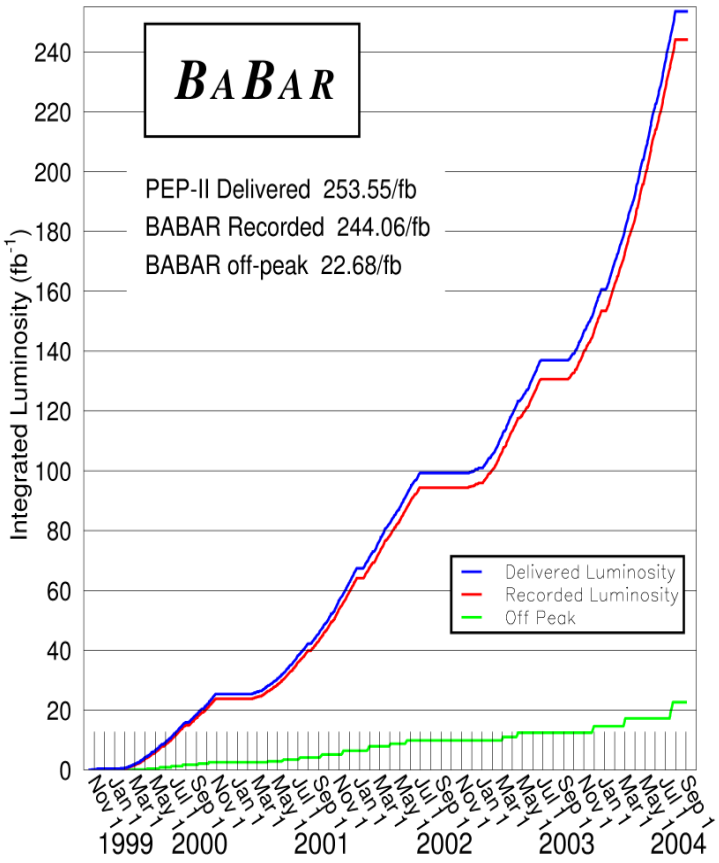


Pre B-Factory era measurements at CLEO:

- $B(\tau^- \to \mu^-\mu^+\mu^-) < 1.9 \times 10^{-6}$ 90% C.L
- $B(\tau^- \to e^+\pi^-\pi^-) < 1.9 \times 10^{-6}$ 90% C.L

The BaBar Detector





- BaBar (at SLAC) has recorded 240 fb^{-1}
- $\tau \rightarrow lll$ (6 modes) uses 91.5 fb^{-1} and $\tau \rightarrow lhh$ (14 modes) uses 221.4 fb^{-1}. Both use on and off peak data.
- Where l = e,μ and h = π,K

Particle Identification (PID)

- For $\tau \rightarrow lll$ events:

➔ Electron (E/P, dE/dx, EMC shower shape) efficiency is 91% with hadron mis-ID rate of 2.2%

➔ Muon (IFR hits, EMC energy deposits) efficiency of 63% with hadron mis-ID rate of 4.8%

- For $\tau \rightarrow lhh$ events:

➔ Electron efficiency is 81% with hadron mis-ID rate of 0.2%

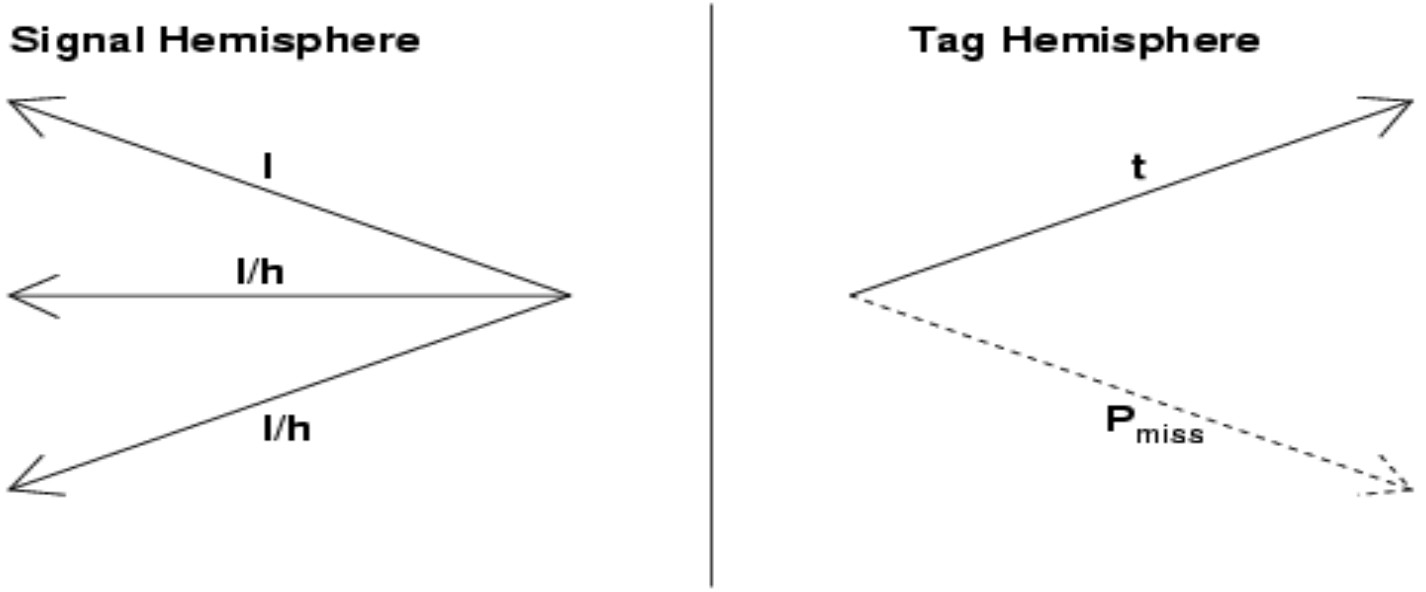
➔ Muon efficiency is 44% with mis-ID rate of 1%

➔ Pion (dE/dx, θ_c) efficiency is 92% with kaon mis-ID rate of 12%

➔ Kaon (dE/dx, θ_c) efficiency is 81% with pion mis-ID rate of 1.4%

- All efficiencies are averaged over momemtum spectrum of decay products – low momentum track reduces efficiency

Analysis Technique (1)



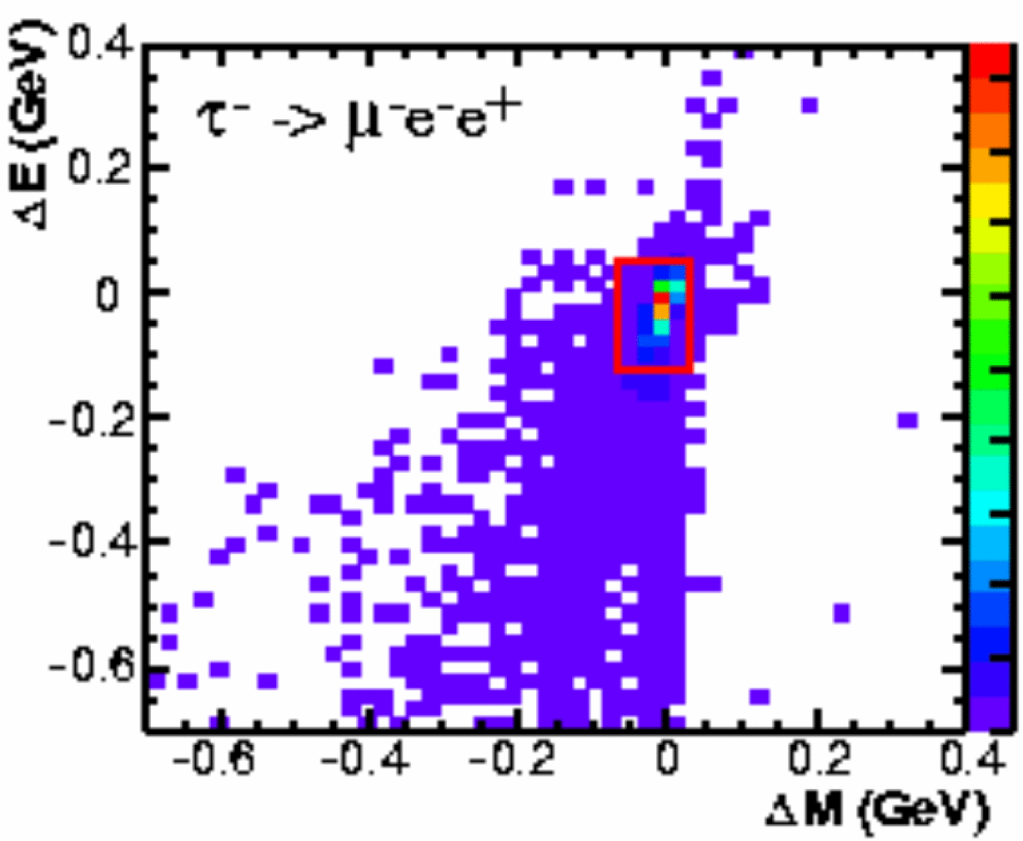
- Tag Side: One well identified tagging track t with missing momentum
- Signal Side: Three tracks, identified by PID, with no υ – leptons (*l*) or hadrons(*h*)

➔ No missing momentum allowed on signal side

Analysis Technique (2)

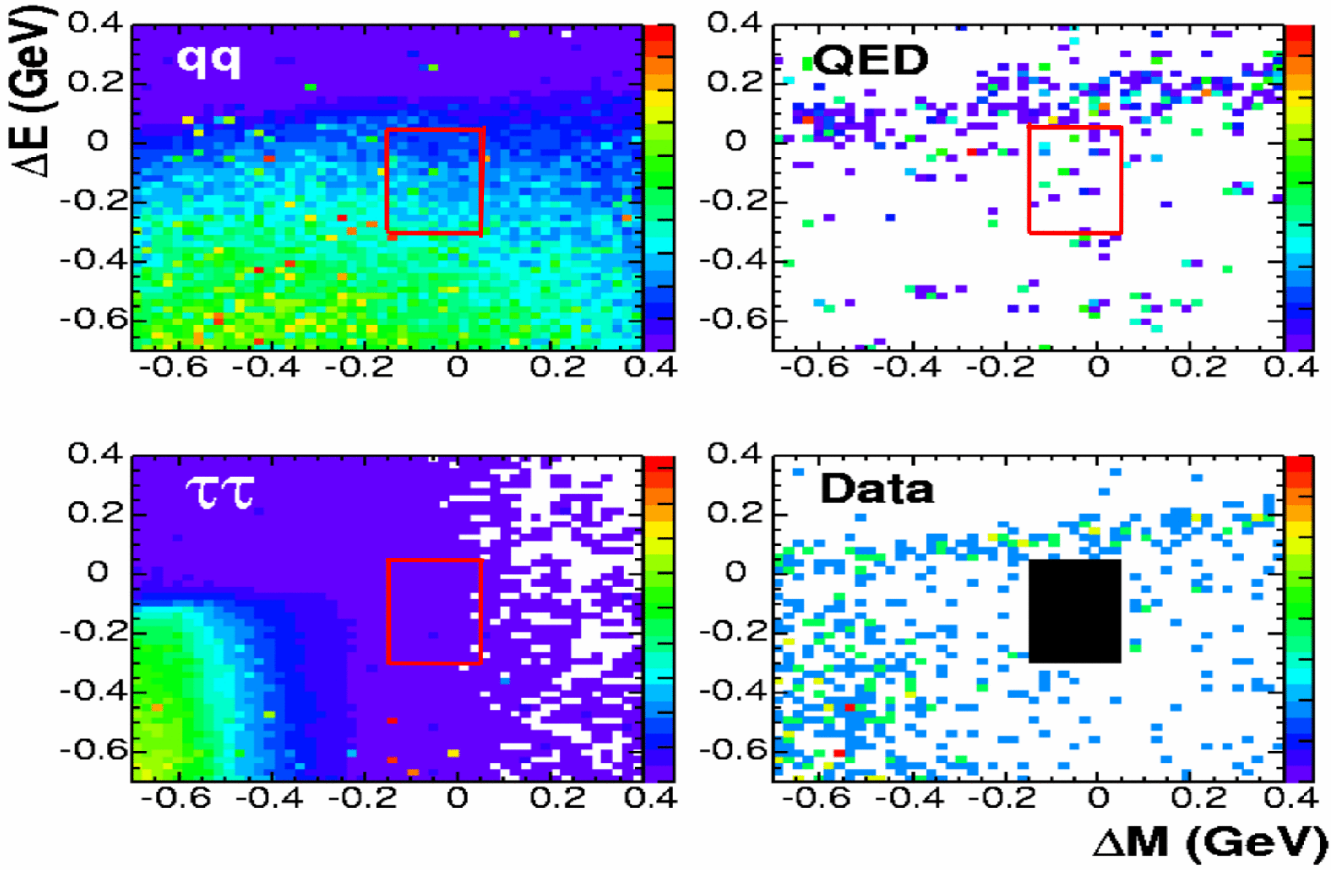
- Use $\Delta M = M_{rec} - M_{\tau}$ and $\Delta E = E_{rec(CM)} - E_{CM}/2$
- Signal has $\Delta M, \Delta E \approx 0$

- $\Delta M, \Delta E$ plane for $\tau \rightarrow \mu$ ee in MC
- Signal box is shown in red



- Expect $\Delta M, \Delta E$ to be smeared by detector and radiative effects
- Signal box is optimised for each channel

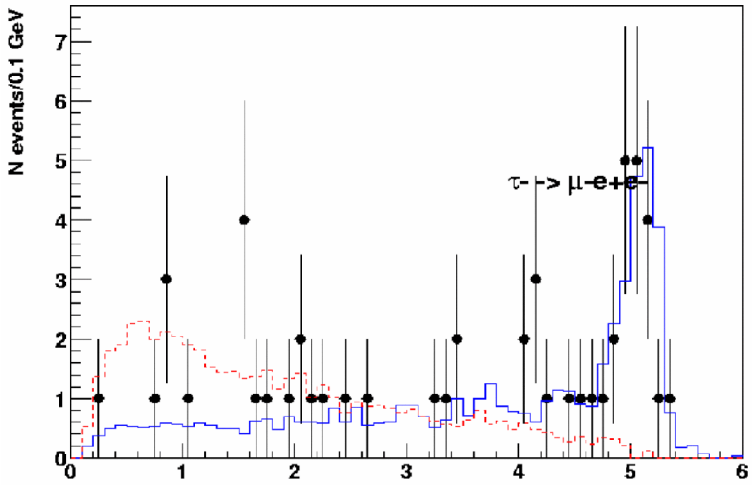
Backgrounds



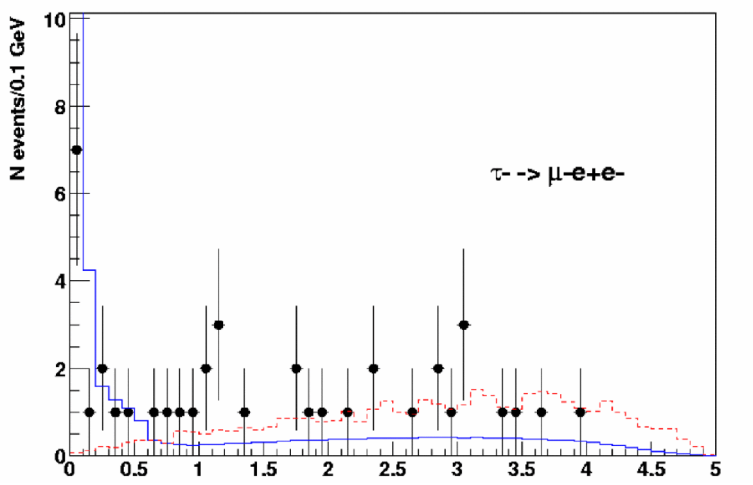
- Tau pair backgrounds at large negative ΔM, ΔE
- $q\bar{q}$ uniformly distributed
- QED is a band at ΔE~0 ($\tau \rightarrow lll$ modes only)

Background Suppression (1)

- Different backgrounds in different channels
- Hence optimise cuts for different channels



1-prong momentum (GeV/c)

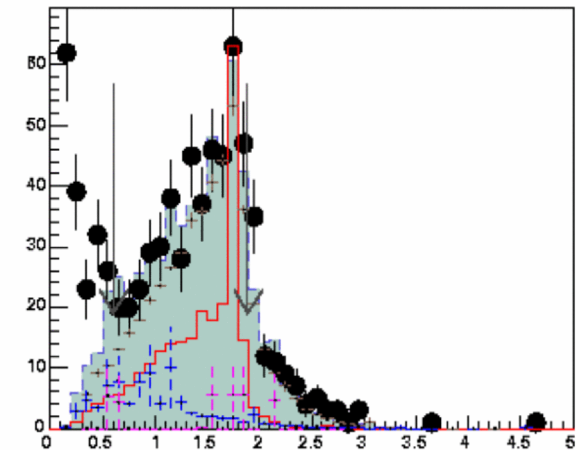


Pt(CM) (GeV/c)

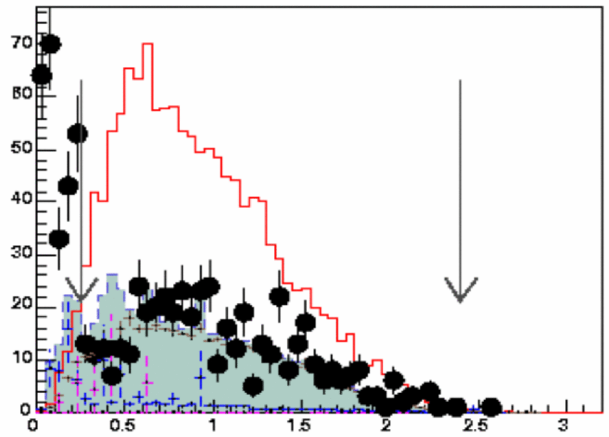
Red – signal events, Blue – background events, black points - data

- P_T(CM) > 100 MeV/c and one-prong momentum < 4.8 GeV/c suppresses Bhabha and di-muon events
- Lepton veto on one-prong further suppresses Bhabha and di-muon events
- Reject gamma conversions

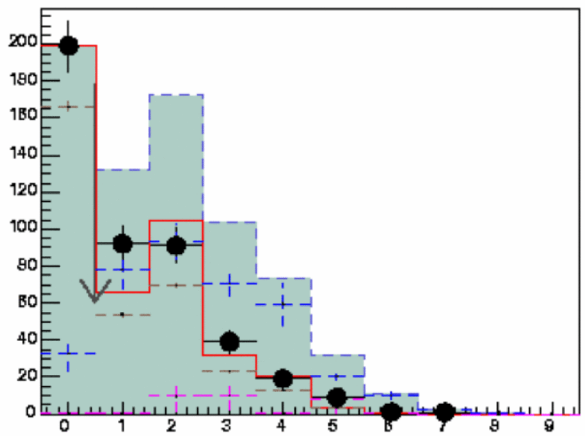
Background Suppression(2)



1-prong mass (GeV)



θ of P_miss (radians)

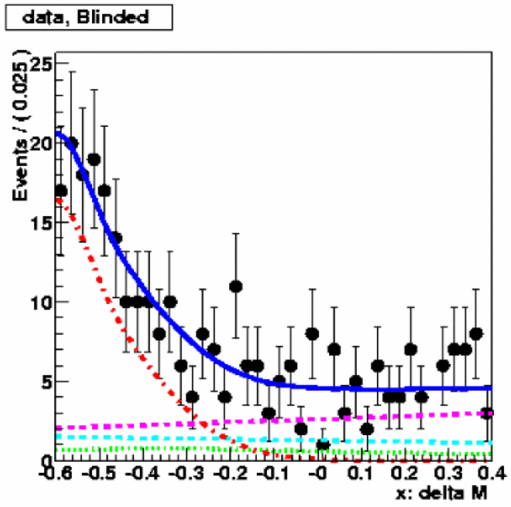


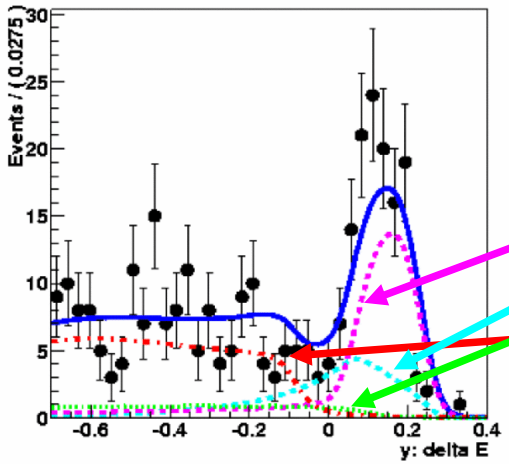
Num 3-prong photons

Red – signal events, Blue – background events, grey– sum of tau pair and qq black points - data.

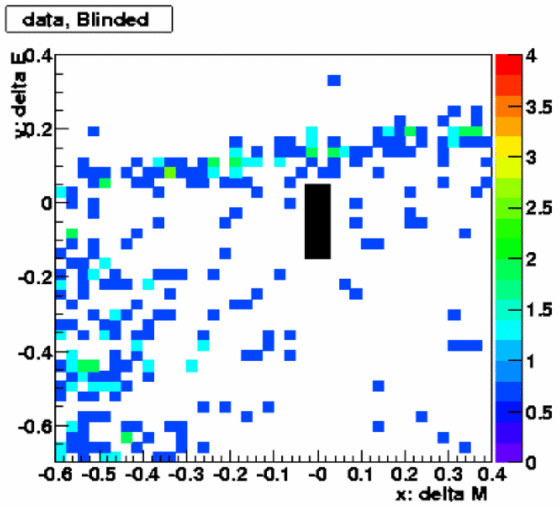
- Theta of missing momentum in range 14 to 137.5 degrees reduces QED backgrounds in lhh modes
- One prong mass > 0.6 GeV (QED) and < 1.9 GeV ($q\bar{q}$, tau pair) in *lhh* modes
- No photons (> 100 MeV) allowed
- No lepton identified as kaon on signal side for all *lll* modes and all *lhh* modes with > 1π

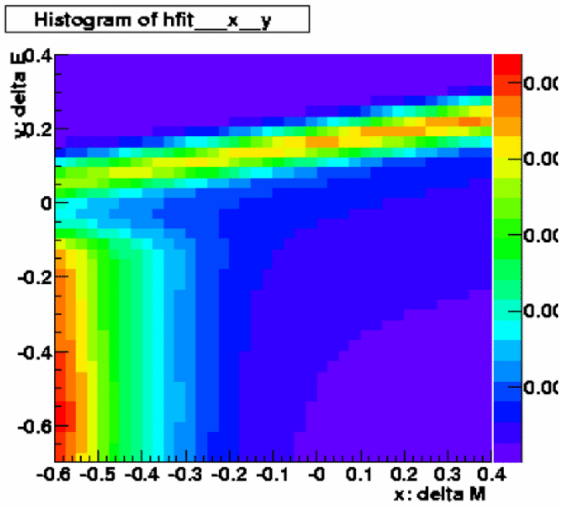
Background Fits to Data





$$P_{data} = f_{QED} * P_{QED} + f_{qq} * (1 - f_{QED}) * P_{qq} + (1 - f_{QED} - f_{qq} * (1 - f_{QED})) P_{\tau\tau}$$





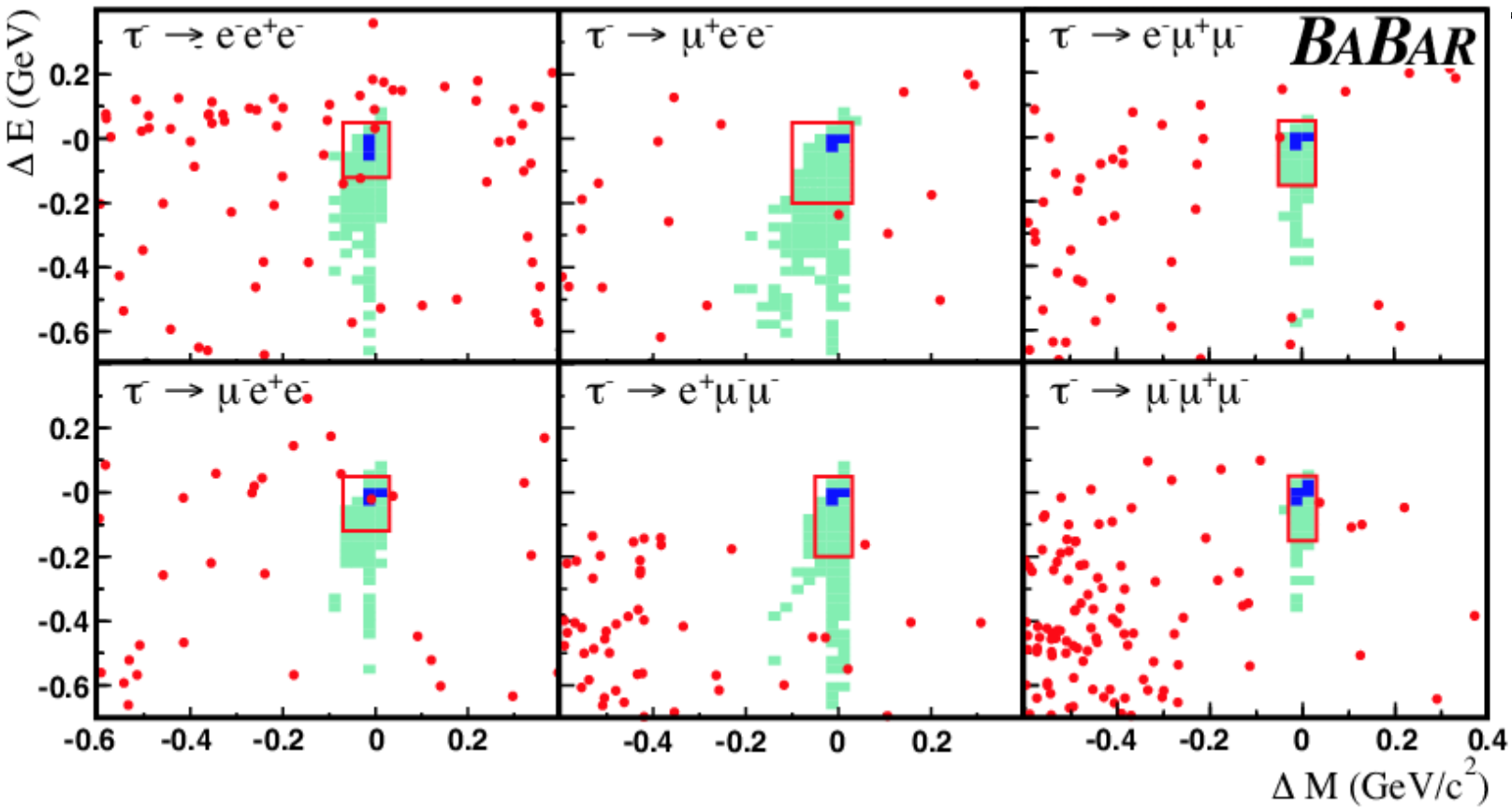
$$N_{BKGR} = N_{GS} * \frac{\int_{SB} P_{data}\, dMdE}{\int_{GS} P_{data}\, dMdE}$$

SB = Signal Box

GS = Grand Sideband

- GS is full ΔM, ΔE plane except the SB
- For τ→*lhh* the QED background is negligible

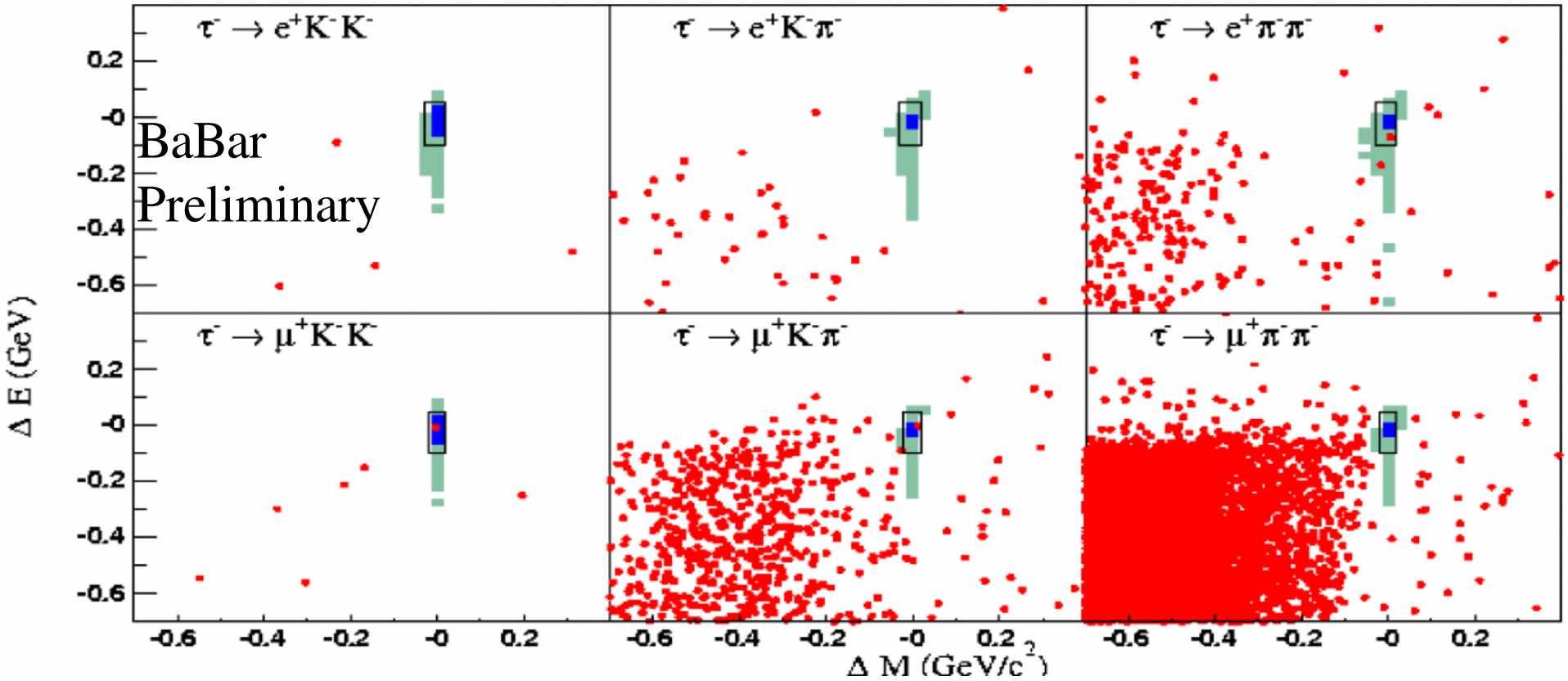
Published Results From $\tau \to lll$ (91.5 fb^{-1})



- PRL 92, 121801 (2004)

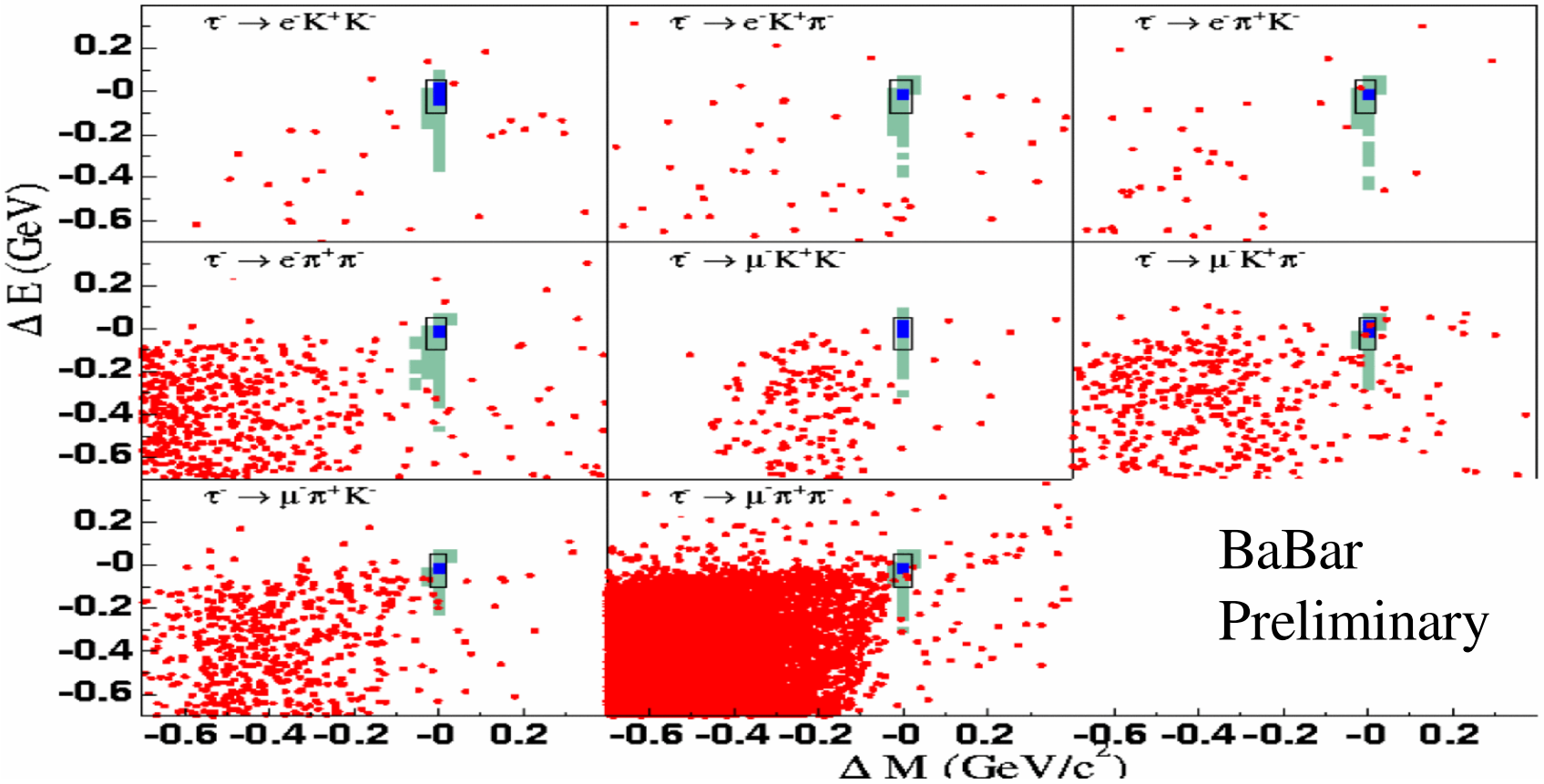
	$e^-e^+e^-$	$\mu^+e^-e^-$	$\mu^-e^+e^-$	$e^+\mu^-\mu^-$	$e^-\mu^+\mu^-$	$\mu^-\mu^+\mu^-$
$\varepsilon(\%)$	7.3 ± 0.2	11.6 ± 0.4	7.7 ± 0.3	9.8 ± 0.5	6.8 ± 0.4	6.7 ± 0.5
N_{bgrd}	1.51 ± 0.11	0.37 ± 0.08	0.62 ± 0.10	0.21 ± 0.07	0.39 ± 0.08	0.31 ± 0.09
N_{obs}	1	0	1	0	1	0
B_{UL90}	2.0×10^{-7}	1.1×10^{-7}	2.7×10^{-7}	1.3×10^{-7}	3.3×10^{-7}	1.9×10^{-7}

Preliminary Results From $\tau \to lhh$ (1) ($221.5\ fb^{-1}$)



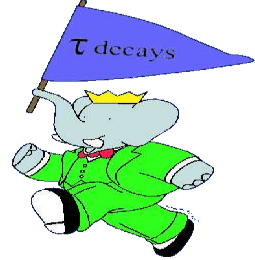
	$e^+K^-K^-$	$e^+K^-\pi^-$	$e^+\pi^-\pi^-$	$\mu^+K^-K^-$	$\mu^+K^-\pi^-$	$\mu^+\pi^-\pi^-$
$\varepsilon(\%)$	3.85 ± 0.16	3.19 ± 0.14	3.40 ± 0.15	2.06 ± 0.11	2.85 ± 0.16	3.30 ± 0.18
N_{bgrd}	0.04 ± 0.04	0.16 ± 0.06	0.41 ± 0.10	0.07 ± 0.10	1.54 ± 0.28	1.46 ± 0.23
N_{obs}	0	0	1	1	1	0
B_{UL90}	1.5×10^{-7}	1.8×10^{-7}	2.7×10^{-7}	4.8×10^{-7}	2.2×10^{-7}	0.7×10^{-7}

Preliminary Results From $\tau \to lhh$ (2) (221.5 fb^{-1})



	$e^-K^+K^-$	$e^-K^+\pi^-$	$e^-\pi^+K^-$	$e^-\pi^+\pi^-$	$\mu^-K^+K^-$	$\mu^-K^+\pi^-$	$\mu^-\pi^+K^-$	$\mu^-\pi^+\pi^-$
$\varepsilon(\%)$	3.77 ± 0.16	3.08 ± 0.13	3.10 ± 0.13	3.30 ± 0.15	2.16 ± 0.12	2.97 ± 0.16	2.87 ± 0.16	3.40 ± 0.19
N_{bgrd}	0.22 ± 0.06	0.32 ± 0.09	0.14 ± 0.06	0.81 ± 0.15	0.24 ± 0.08	1.67 ± 0.32	1.04 ± 0.20	2.99 ± 0.42
N_{obs}	0	0	1	0	0	2	1	3
B_{UL90}	1.4×10^{-7}	1.7×10^{-7}	3.2×10^{-7}	1.2×10^{-7}	2.5×10^{-7}	3.2×10^{-7}	2.6×10^{-7}	2.9×10^{-7}

B-Factory Era Results



- Belle and BaBar have pushed $\tau \rightarrow lll$ limits to $O(10^{-7})$
- PLB 589, 103 (2004) - Belle
- PRL 92, 121801 (2004) – BaBar

  ➔BaBar expected 3.41 background events and found 3

- BaBar has new results on $\tau \rightarrow lhh$ at 10^{-7} level

➔Expected 11.11 background events and found 10

- Other modes eg $\tau \rightarrow \mu\gamma$ at 10^{-7} from BaBar/Belle
- Also $\tau \rightarrow e\gamma$, $\tau \rightarrow l\eta$ and $\tau \rightarrow l\pi$ (Belle) at 10^{-7} level
- Lots more data to come!

Conclusions

- No signal is found and have set limits O(10^{-7}) for 20 LFV modes (6 *lll* and 14 preliminary *lhh*)

- Limits have met up with upper end of theoretical predictions
  - ➔Eg SUSY with Higgs Triplet - B($\tau \rightarrow lll$) is 10^{-7}

- Lots more tau results on the way with 220 fb^{-1}data

- Can probe 10^{-8} (SUSY) region with higher statistics